Measurement of *in situ* Acoustic Properties for the ONR Geoclutter Program

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LONG-TERM GOALS

The long-term goal of the Geoclutter program is to understand the causes and implications of geologic clutter/reverberation in a seismically and geologically well-characterized shallow-water environment. The selected field area is the mid-outer continental shelf off New Jersey; the bathymetry (a known and prominent cause of backscatter) and portions of the shallow subsurface of this area have been mapped in detail as part of the ONR STRATAFORM program. One premise of this work is that, in any littoral area, buried geologic features can contribute significantly to acoustic reverberation, which affects tactical ASW sonar systems. Proper acoustic processing, coupled with quantitative geologic models, can be used to distinguish these buried features from real (man-made) targets. Complexity arises from STRATAFORM studies on the continental shelf off New Jersey that have shown the general lack of predictability of the shallow subsurface using seafloor imagery, even with 100% coverage of the seafloor and dense grids of subsurface data to depths of 10-15 m.

SCIENTIFIC OBJECTIVES

The overall scientific objectives of the Geoclutter program are to: 1) to understand, characterize, and predict lateral and vertical, naturally-occurring heterogeneities that may produce discrete acoustic returns at low grazing angles (i.e., "geologic clutter") in a mid-outer shelf test site off the U.S. (New Jersey), and then 2) to conduct precise acoustic reverberation experiments at this site to understand, characterize, and potentially mitigate the geologic clutter, so that the false alarms, or detects, of tactical sonar systems encountered in this marine geologic environment can be characterized properly. The specific goal of our work is to support these objectives with the development and deployment of a device designed to measure, *in situ,* the spatial variability of sound speed and potentially attenuation in near-surface sediments at the Geoclutter site. These measurements will then be combined with the data collected by other investigators to better understand acoustic reverberation from the seabed in shallow water, with the objective of designing signal processing ("detection") algorithms that will distinguish naturally occurring features like shallowly buried meandering channels, surface outcrops of reflective horizons, and erosion scars from man-made targets of similar dimensions (e.g., submarines).

APPROACH

To properly implement acoustic models for the Geoclutter area we first need to know or predict the key acoustic and physical properties throughout the volume of interest (i.e., grain size, density, sound speed, attenutation). The sediments right at the seafloor are particularly important. The seafloor

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14. ABSTRACT
The long-term goal of the Geoclutter program is to understand the causes and implications of geologic clutter/reverberation in a seismically and geologically well-characterized shallow-water environment. The selected field area is the mid-outer continental shelf off New Jersey; the bathymetry (a known and prominent cause of backscatter) and portions of the shallow subsurface of this area have been mapped in detail as part of the ONR STRATAFORM program. One premise of this work is that, in any littoral area, buried geologic features can contribute significantly to acoustic reverberation, which affects tactical ASW sonar systems. Proper acoustic processing, coupled with quantitative geologic models, can be used to distinguish these buried features from real (man-made) targets. Complexity arises from STRATAFORM studies on the continental shelf off New Jersey that have shown the general lack of predictability of the shallow subsurface using seafloor imagery, even with 100% coverage of the seafloor and dense grids of subsurface data to depths of 10-15 m.

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within the Geoclutter area has already been surveyed at 95 kHz with multibeam bathymetry and sidescan backscatter as part of the ONR STRATAFORM program. The backscatter data, may, in fact, provide substantial information on seafloor sediment properties, but indirectly as the relationship between backscatter and sediment properties remains ambiguous. Our approach to addressing this issue is to combine direct sampling (being conducted by teams from the University of Texas and the University of Delaware) and *in situ* measurements of sound-speed and potentially attenuation, supported by video imagery of the seafloor at the sample location. Sampling and *in situ* measurements would be conducted on a dedicated cruise of the *R/V Cape Henlopen* scheduled for August 2001. This cruise would be part of a series of experiments in the Geoclutter area carried out over the summer of 2001 including direct measurement of reverberation by researchers from MIT and a chirp sonar profiling conducted by researchers from Florida Atlantic University.

In support of the Geoclutter program, we have developed, built, and deployed a relatively inexpensive, robust, ship-deployable device (**ISSAP – I**n situ **S**ound **S**peed and **A**ttenuation **P**robe) for measuring sound speed and attenuation in near-surface sediments. Measurements of *in situ* acoustic properties are particularly critical in the sandy sediments off New Jersey as these sediments tend to quickly dewater making laboratory measurements difficult.

The system uses four 2.54 cm (diameter) by 20 cm long probes that are inserted into the seafloor by 180 kg of reaction weight deployed on a coaxial cable free-swinging within a protective tripod that allows the probes to be inserted vertically on slopes up to 20 degrees (Fig 1). The probes operate at frequencies of either 50 or 100 kHz and are arranged in a diamond shaped pattern with nominal path separations of 20 or 30 cm. An onboard computer and topside electronics control the paths selected and the number of measurements per path. A typical deployment involves measurements across five paths including both long (30 cm) and short (20 cm) paths. Along with the acoustic probes, the ISSAP also has a color video camera that provides imagery of the seafloor and the probes as they penetrate, a 50 kHz altimeter to independently monitor height off the bottom, and temperature, pressure, pitch, roll, and heading sensors to monitor the stability and orientation of the platform. Finally, a bottom sense switch provides yet another indication of the platforms height above the bottom.

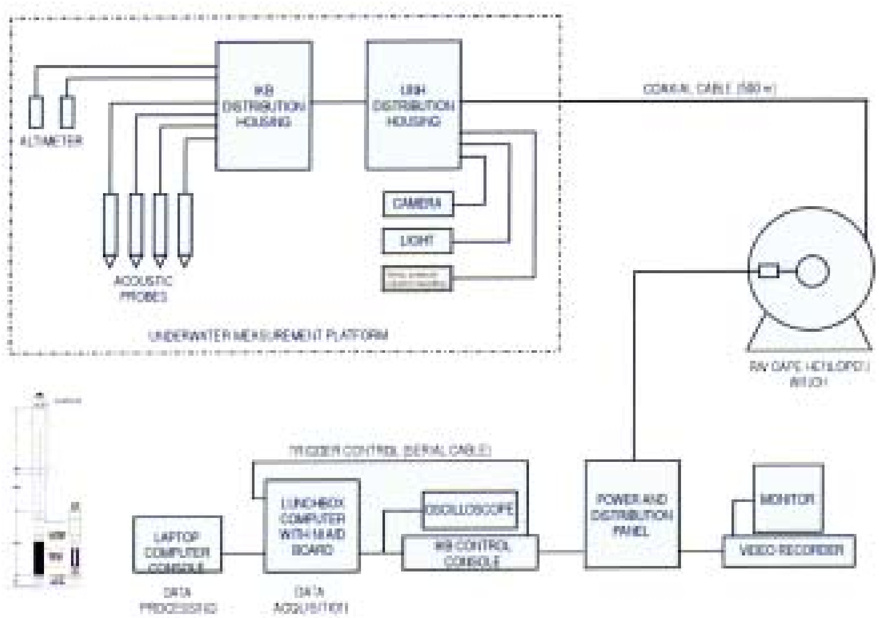

Fig. 1. Block diagram of major components of ISSAP – insert on the bottom left is detail of probe.

The system is lowered to the bottom on a coaxial cable until the altimeter, bottom sense switch and camera indicate proximity to the bottom. When the bottom is in sight, a bottom water measurement cycle is initiated with a short (40 microsecond) pulse transmitted from one of the probes and received by another. Ten measurements are made across each of five paths for a total of 50 measurements. This is repeated 3 times for a total of 150 measurements in a measurement cycle. Upon completion of the bottom water measurement cycle the system is lowered into the seafloor where two measurement cycles of 150 measurements each over the 5 paths are made in the sediment. When both sediment measurement cycles are complete, the system is pulled out of the seafloor and another bottom water measurement cycle is completed. A sampling station thus typically consists of two bottom water cycles and two sediment cycles with a total of 600 independent measurements of acoustic travel time over 5 independent paths with different separations.

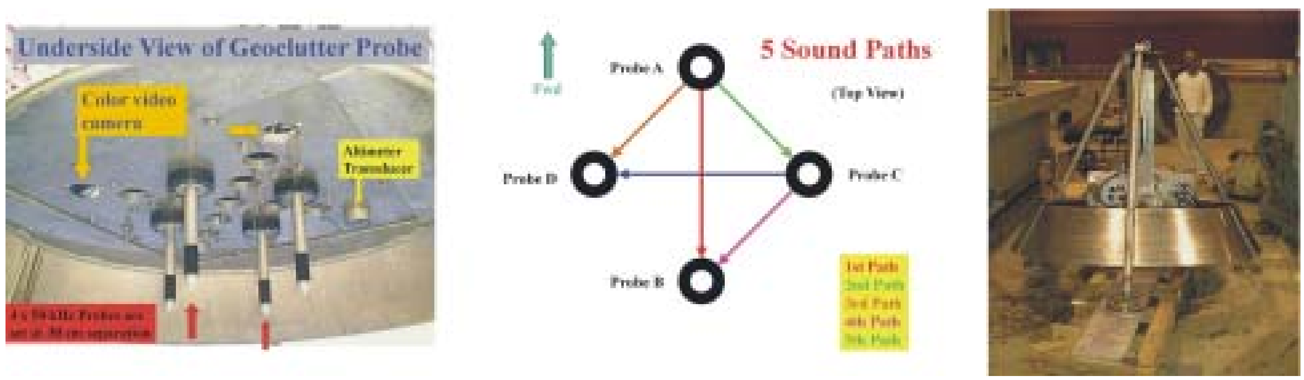

Fig 2. Underside view of ISSAP showing orientation of probes (left),diagram showing 5 paths used for sound speed and attenuation measurement (middle) and photo of tripod and probe assembly (right).

The transmit and receive pulse for each measurement is sent up the coax and digitized at 2 MHz on the topside acquisition computer and sent to a processing computer. An entire measurement cycle (150 measurements) takes less than one minute and results in approximately 75 Mbytes of data. A typical station (2 bottom water and two sediment cycle) produces about 300 Mbytes of data. The fundamental measurement is that of the travel time (time-of-flight) between the transmit and received pulse. Travel times are determined by several methods (threshold, zero-crossing and correlation techniques) and converted to sound-speed through a calibration process. There are two levels of calibration available. The most precise involves collecting data in distilled water at a known temperature and using the well-established variation in sound speed with temperature to precisely determine the separation of each pair of transducers. This is done at the beginning, end and several times during a cruise. We also carry out an ongoing calibration by measuring the speed of sound in seawater (at known temperature) before and after each penetration into the seafloor. These bottom water calibrations also allow us to determine if the insertion of the probes into the bottom resulted in a change in their relative path length.

Along with measurement of time-of-flight (and thus sound speed) we can also compare the digitized pulses to attempt to measure sediment attenuation. Several approaches will be used to measure attenuation. The relative amplitude of the received wave forms over the different path-lengths is one indication of attenuation as is the spectral ratio (or difference) between the sea water received waveform and the sediment received waveform. Finally we will use the filter correlation technique of

Courtney and Mayer (1993) that was developed especially for short time series of the type we are measuring.

WORK COMPLETED

Design of the ISSAP began in Sept. 2000 with construction commencing in November 2000. Several generations of prototype probes were constructed and tested until a final design was established. Laboratory tests were also carried out to determine the reaction weight needed to insert the probes in the type of sediment expected in the Geoclutter area as well as the maximum separation over which signals could be propagated. Wet-end components were pressure tested in May at the high-pressure testing facilities of the Portsmouth Naval Shipyard, the tripod mechanics tested in the test-tank facilities of the University of New Hampshire and the complete system was field tested in Portsmouth Harbor in mid July. The University of Delaware greatly facilitated these tests by delivering to UNH the actual winch and wire to be used during the field program. The system was certified ready and driven to Lewes Delaware on July 28th for deployment on *R/V Cape Henlopen* Cruise 01-17.

RESULTS

The ISSAP was deployed in the Geoclutter area off New Jersey on the *R/V Cape Henlopen* between 30 July and 5 August. The system performed flawlessly recovering water column and sediment data at 99 stations selected to represent a range of seafloor backscatter types. More than 40 gigabytes of digital data was collected as well as more than 20 hours of video. While the detailed analyses of these data have only just begun, initial observations indicate that the data are of excellent quality (Fig 3).

Calibration runs resulted in a standard deviation of .354 m/sec. Overall variation of the bottom water measurements over the 99 stations was less than 4 m/sec with standard deviations being less than one meter per second at any given site (well within the expected change due to small variations in bottom water temperature) and indicating that the system geometry remained constant and timing precise. Real and substantial variations in seafloor sound speed were measured (station values ranged from a low of approximately 1570 m/sec to highs of over 2000 m/sec) with an apparent (an not unsurprising) correlation between increased sound speed and higher backscatter. The system was deployed in sediments ranging from muddy, silty sands to gravels and shell hash deposits with a video record of each deployment site also recorded.

While we were uncertain that we would be able to also measure attenuation when we proposed the development of the ISSAP, the clean recovery of well developed waveforms (Fig 3) gives us confidence that we will also be able to extract attenuation values at most if not all of the stations. Most importantly, the tremendous redundancy of our measurements at each station (approx. 300 measurements) will allow us to put well grounded confidence limits on our measurements and thus understand the true local variability of sound speed and attenuation in the Geoclutter area.

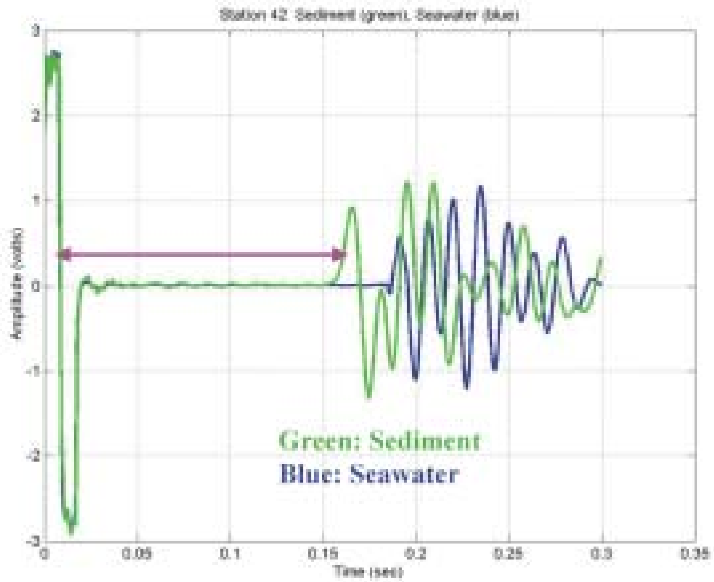

Fig. 3. Example of water and sediment waveforms recorded at each station. The difference in travel time is a measure of the difference in sound speed; the difference in spectral components is a measure of the attenuation in the sediment.

IMPACT/APPLICATIONS

Using this system we hope to be able to get a reasonable idea of the lateral distribution of sound speed and attenuation variations within the Geoclutter area. These measurements will be compared directly to backscatter values from the multibeam system and to the predictions of impedance and attenuation made from the Chirp Sonar by Schock.

Sediment properties at depth will be established both directly, through long coring and borehole logging, and indirectly, through analysis of the multifrequency CHIRP data. We anticipate that long coring will take place as part of the last phase of the ONR STRATAFORM program (Austin is the lead PI for this project and Olson a co-PI).

The work described above will play a key part in the overall development of robust seafloor characterization approaches, particularly through helping to better constrain the relationship of high-frequency backscatter to seafloor properties. It will also provide critical information on the relationship of *in situ* properties to those made in the laboratory as well as those extracted remotely from the inversion of seismic (Chirp Sonar) data.

TRANSITIONS

None yet.

RELATED PROJECTS

STRATAFORM, and other Geoclutter projects including those by Goff, Summerfield and Schock.

REFERENCES

Courtney, R.C., and Mayer, L.A., 1993b, Calculation of acoustic parameters by a filter correlation method, J. Acoust. Soc. America, v. 93, n. 2, p. 1145 – 1154.